# Roentgen Cardiac Kymography:

## Electrocardiographic Correlation

S. F. THOMAS, M.D.,* *Palo Alto*, and L. H. GARLAND, M.D.,† *San Francisco*

THE purpose of this paper is to re-evaluate the roentgen cardiac kymogram and to demonstrate that the kymogram sometimes gives information which is not obtainable by any other means.

### INTRODUCTION

Single slit roentgen kymography was introduced by Sabat in 1911.[5] Crane,[1] in 1916, published the first American paper dealing with the use of the method. Since that time, one major improvement has been made, the perfection of the multiple slit kymograph by Stumpf in 1928.[9] Hirsch[4] published his first paper on the use of this instrument in this country in 1934. There has been considerable work on the application of this type of kymograph; but, in the past few years, little has been added to the literature by way of evaluation of this particular method of examination and it is felt that reconsideration at this time would be worth while, especially as we feel much as Schwedel[7] does: "Roentgenkymography has made definite contributions to cardiac roentgenology. It makes possible a permanent record of cardiac motion. It permits analysis of the pulsations of the heart and the great vessels as to amplitude and time. ... Like all newer methods, roentgenkymography has gone through an initial period of exploitation and exaggerated claims, and, currently, it has largely fallen into disuse. But in the coming years this method will no doubt be more adequately evaluated on the basis of its actual usefulness in cardiac roentgenology."

The kymograph, which was used in this work, was of a conventional type, with 0.4 mm. slits in a lead plate, and a film excursion of 12 mm. The obvious usefulness of this multiple slit machine over the single slit is that it allowed a complete study of the whole organ simultaneously. The other advantage is that one area can be compared with another during the same interval. The single slit method (in some instances) gave a more detailed view of the movement, but it did not allow viewing the organ as a whole, nor did it allow for any cyclic timing of the various parts of an organ. This is especially necessary in cardiac roentgenkymography. The usefulness of the comparison of the waves of the various chambers simultaneously is, of course, obvious. The addition of a timing device for the duration of the exposure is also useful.

### TECHNIC

Routinely, exposures of 1½ to 2 seconds were made in mid-inspiration with the patient as relaxed

as possible in order to avoid a Valsalva or Müller effect. Films in forced inspiration and expiration were made on occasion to confirm or rule out certain minimal findings. Projections were made in the P.A. position, and in most instances, both oblique positions (RAO 45°; LAO 65°), using a 48 inch distance. The oblique views were desirable to provide projections in other planes and occasionally were necessary to eliminate misleading "pendulum motion" or "sagittal plane" contraction, both resulting in poor lateral excursion, and consequently low waves on the P.A. kymogram.[6]

### CRITERIA FOR KYMOGRAPHIC DIAGNOSIS

The criteria for kymographic diagnosis are the depth (or height), shape, and phase of the waves.[9,10] The depth of the waves is considered relatively important. While the normal is quoted as ranging from 4 to 8 mm., often without specification of the target-film distance used, we found that in most of the cases in this series the waves were usually under 4 mm. in depth (See Figure 1). However, in the cases with myocardial disease of any type, the height (or depth) of the waves is often 2 mm. and frequently less than 1 mm. (All measurements made directly on the 48 inch distance film). Other findings sometimes suggestive of disease in the myocardium are "peaking" of the waves where the waves come to an abrupt point.

Splintering of the waves (both systolic and diastolic) was regarded as important in the diagnosis of disease, especially when it is accompanied by waves of low amplitude which appear fuzzy (unsharp), (See Figures 2, 5, and 6). Of course, the suppression of waves or absence of movement (so-called "silent frames") or the outright reversal of movement (so-called "paradoxical frames") in any area was considered diagnostic of myocardial damage, and when this occurred in the persence of suitable associated findings, an area of infarction was diagnosed. Localized adhesive pericarditis may produce suppressed and fuzzy waves and mimic an area of localized myocardial damage, but the condition was not encountered in this series.

The term, myocardial damage, is used in this report to include various cardiac abnormalities from myocarditis through myofibrosis to frank infarction. This term was used in this same broad sense in reference to interpretations of both the kymograms and electrocardiograms.

### RESULTS

Because most of this study was done on Naval personnel, the average age of our cases (38 years) is somewhat less than one might expect in a general hospital. In the cases with a clinical diagnosis of
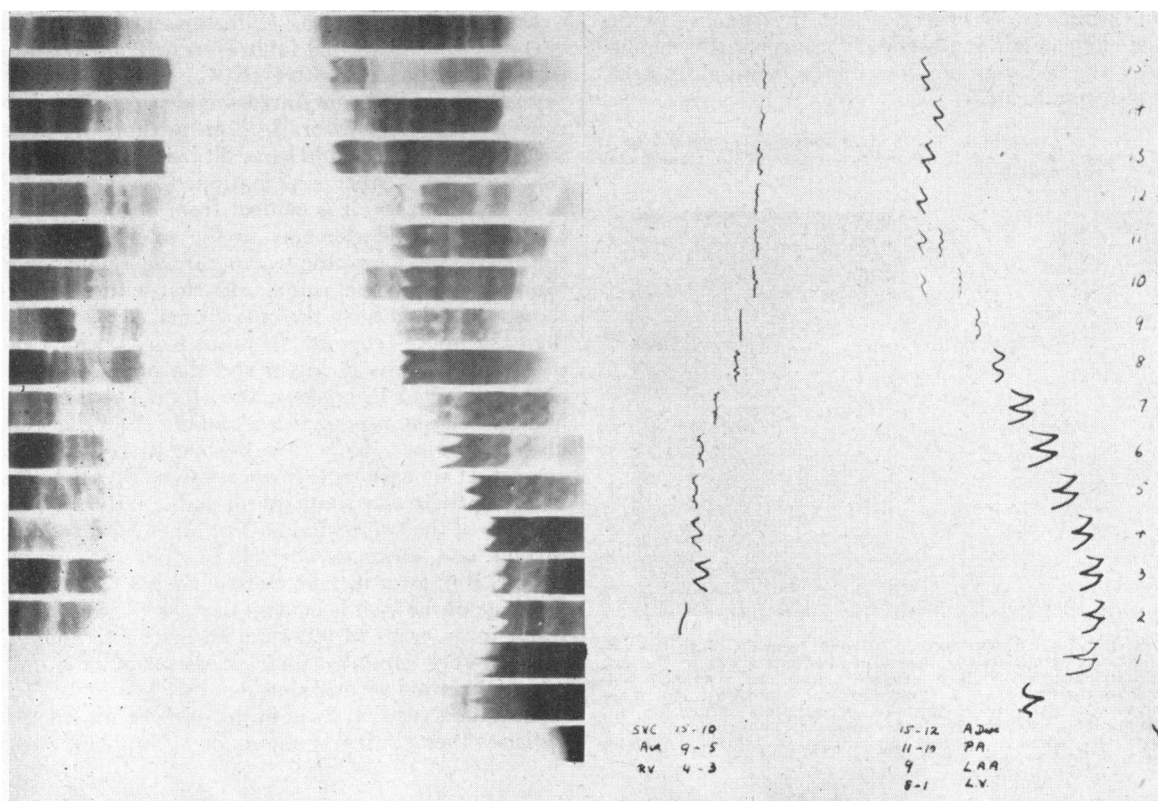
Figure 1.—Roentgen kymogram of a healthy adult, age 30, with tracing to illustrate the various types of waves normally present over the cardiovascular silhouette. The numbers refer to the individual "frames" above the left hemidiaphragm. P.A. view.

coronary artery disease, angina pectoris, or hypertension, the average age was 44.5 years.

Over 350 sets of kymograms were made. Of these, 275 cases are available for review. Two hundred and forty-nine of the patients had one or more electrocardiograms, so that a comparative test of the two methods of diagnosis of cardiac disease could be made.

To test the reliability of cardiac roentgenkymography on our miscellaneous group* we decided to use the electrocardiogram as an accepted test for the diagnosis of major cardiac disease and then match the kymogram against this method. In many instances, only single electrocardiograms (and kymograms) were made, but in other instances, serial tracings and x-ray studies were made. The electrocardiograph used was usually a "Cambridge Simpli-Trol" and occasionally a "Sanborn Cardiette." The leads were the standard limb leads and the IVF (the exploring electrode over the cardiac apex, and the indifferent lead on the left ankle). Most of the interpretations were made by Maurice Sokolow (then Lt. Comdr. MC, USNR). All interpretations of electrocardiograms were accepted as written in the clinical record and no "special emphasis" on reinterpretation was attempted, in order to insure an

* The group comprised patients with various suspected or known cardiac disorders, and ranged from functional disturbances following tsutsugamuchi disease to frank coronary occlusion.

evaluation of the observed results of day-to-day clinical tests. The two methods correlated in 80.5 per cent of the cases, or 201 patients (See Table 1). There was a failure of correlation in 19.5 per cent, or 48 patients.

To test the methods against one another, figures were subjected to statistical analysis (Chi square

TABLE 1.—Correlation of Kymograms and Electrocardiograms in the Diagnosis of Myocardial Disease
(249 cases)

|  | Cases | Per Cent |
|---|---|---|
| Kymo and ECG positive | 28 | 11.3 |
| Kymo and ECG negative | 146 | 58.4 |
| Kymo and ECG questionable | 27 | 10.8 |
| Total correlated | 201 | 80.5 |
| Kymo negative, ECG positive | 8 | 3.3 |
| Kymo positive, ECG negative | 12 | 4.8 |
| Kymo positive, ECG questionable | 3 | 1.3 |
| Kymo questionable, ECG positive | 5 | 2.0 |
| Kymo questionable, ECG negative | 8 | 3.3 |
| Kymo negative, ECG questionable | 12 | 4.8 |
| Total failure of correlation | 48 | 19.5 |

Note: The Kymograms were made within three to five days of the electrocardiograms in the vast majority of instances.

The term myocardial disease includes miscellaneous cardiac disorders ranging from myocarditis to frank infarction.

test), and it was observed that the chances of the particular figures observed occurring by chance would be less than one in a hundred, which is statistically significant.[†]

[†] We are grateful to Dr. Frank Weymouth, Professor of Physiology, Stanford University, for his aid in interpretation of the statistics.
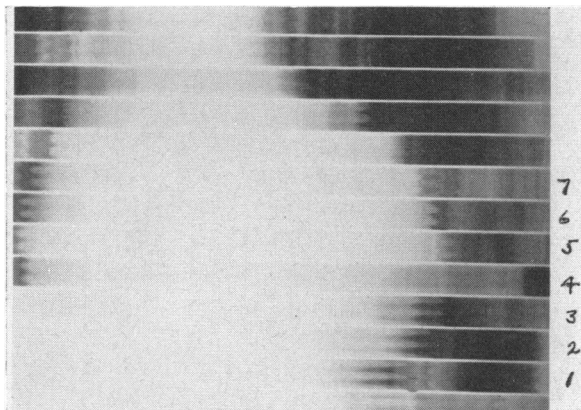


Figure 2.—P.A. kymogram of male, age 54. Note the absence of normal waves in frame number 4 above the left hemidiaphragm ("silent" frame); and the reversed pattern in frames 5 to 7 ("paradoxical" motion). Roentgen diagnosis: myocardial damage, presumably infarction, involving the wall of the left ventricle. The patient was a physician with a clinical diagnosis of infarct. Autopsy verification 2½ weeks later.

Further analysis of the 48 instances of "failure of correlation" reveals that failures were made in a positive (Kymo) and negative (ECG) fashion and vice versa 20 times. It is not unreasonable to assume these represent inherent errors in both methods of examination. If so, this would leave 28 cases wherein there was need for further explanation. However, in this group of 28 cases, it is evident from Table 1 that all had questionable elements in the interpretation of the electrocardiographic tracing or the kymographic film; therefore, the actual aid that either one of these tests *might* be to the other is more considerable than the figures suggest. In other words, where one of these tests was positive, and the other questionable, one acted to confirm the other. On the other hand, when one was negative, and the other questionable, it is more likely that the negative result was correct. If we assume this, we resolve 28 of the cases in which there was some questionable failure of correlation of the two methods. The other 20 cases need further and more detailed individual case-by-case review. But, even if there were adequate explanation for none of these, it is evident that the overall figures result in an error of less than 10 per cent, which in clinical work must be regarded as proof of a quite reliable method of examination.

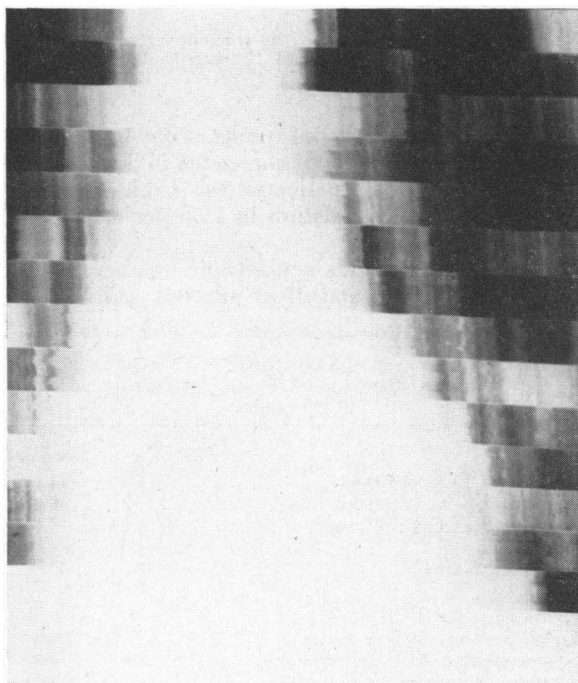Roentgen cardiac kymography is not intended to replace other clinical methods or to supplant roent-



Figure 5.—P.A. kymogram of male, age 36. Note the very poor amplitude of the waves over the entire left side of the heart and over the lower half of the right. *These findings were also present in both the L.A.O. and R.A.O. projections.* Roentgen diagnosis: myocardial disease, severe probably infarction. Clinically, the patient had substernal pain and dyspnea, but his *ECG was repeatedly negative* before and after the kymograms were made. He was allowed to go on leave. After sprinting to catch a train his attacks recurred. The ECG findings then showed changes suggestive of coronary disease. Clinical diagnosis: Coronary occlusion.
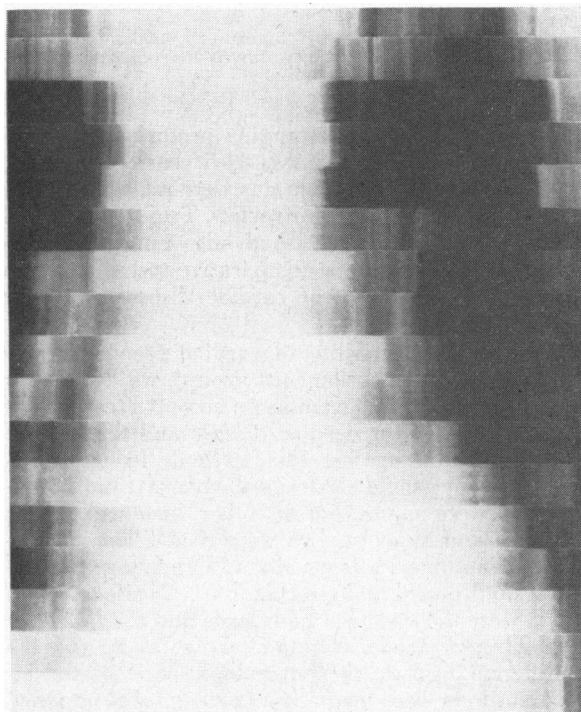


Figure 6.—P.A. kymogram of male, age 48. Note the shallow or paradoxical pulsation over most of the left ventricular border. ECG made the day before entry was negative. Clinical story questionable. Patient was released from hospital for ambulatory convalescence at home five weeks later and kymogram still showed evidence of a marked amount of myocardial damage. He developed acute substernal pain within 24 hours of departure from the hospital. Autopsy next day disclosed acute and recent infarction.

genoscopy or roentgenography. Properly interpreted, roentgen kymograms have been demonstrated here as a reliable source of additional information, and in a small percentage of cases can provide information not obtainable clinically or even by ECG.[2,3,8,11]

## SUMMARY

A review of 249 cases in which both roentgen cardiac kymograms and electrocardiograms had been made confirms that the roentgen kymograph is a useful method of examination of the heart in clinically suspected cases and may give information
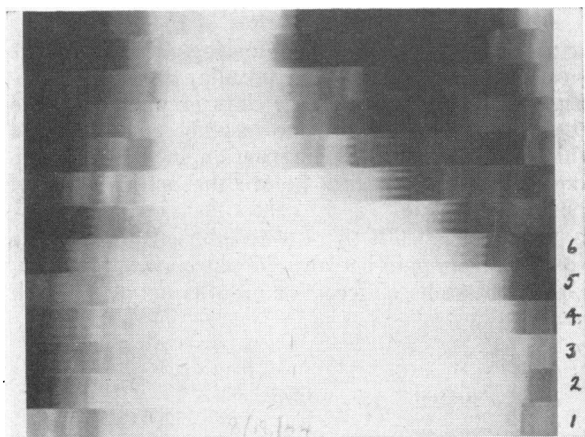
Figure 3.—P.A. kymogram of a male, age 31. Note the "silent" frames, numbers 1, 2, and 3 above the left hemidiaphragm, indicating apparent absence of lateral motion in this area; very shallow amplitude of pulsation in frames 4 to 6 ("damped" motion). *These findings were also present in the L.A.O. projection.* Roentgen diagnosis: localized myocardial damage. Clinically, the patient had a stab wound in the heart. The ECG interpretation was "acute pericarditis."
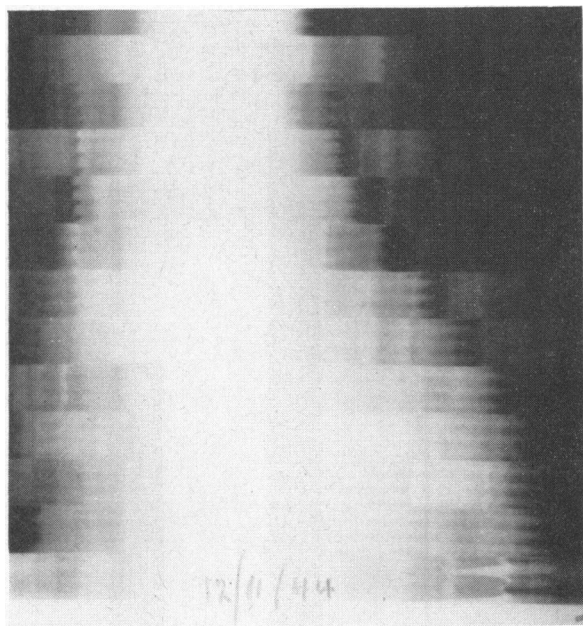


Figure 4.—Same case four months later. Note return of normal motion over the lower half of the cardiovascular silhouette on the left. Clinically well. ECG also returned to within normal limits.

which is not obtainable by any other method. Two hundred and one cases (80.5 per cent) correlated with the electrocardiogram. Forty-eight cases (19.5 per cent) did not correlate with the electrical tracing. Illustrative cases are used to bring out the various points of interest:

1. A case with autopsy proof exemplifying a typical myocardial infarct.

2. A case with autopsy proof of myocardial infarct in which the electrocardiogram was negative and the kymogram positive.

3. A case of a stab wound of the heart (Figures 3 and 4) in which the initial electrocardiogram showed evidence only of pericarditis while the kymogram was positive for localized myocardial damage. Subsequently, the electrocardiogram became positive, and ultimately, both sets of tests disclosed return to normal patterns.

## CONCLUSIONS

1. The roentgen cardiac kymogram provides a permanent record of cardiac pulsations.

2. Correlation of the roentgen kymogram with the electrocardiogram is good.

3. In cases of suspected myocardial disease in which the electrocardiogram is negative, the roentgen kymogram may provide invaluable diagnostic information, especially in cases of myocardial infarction.

4. The roentgen kymogram may serve to corroborate the correct clinical diagnosis when the electrocardiogram is inconclusive.

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